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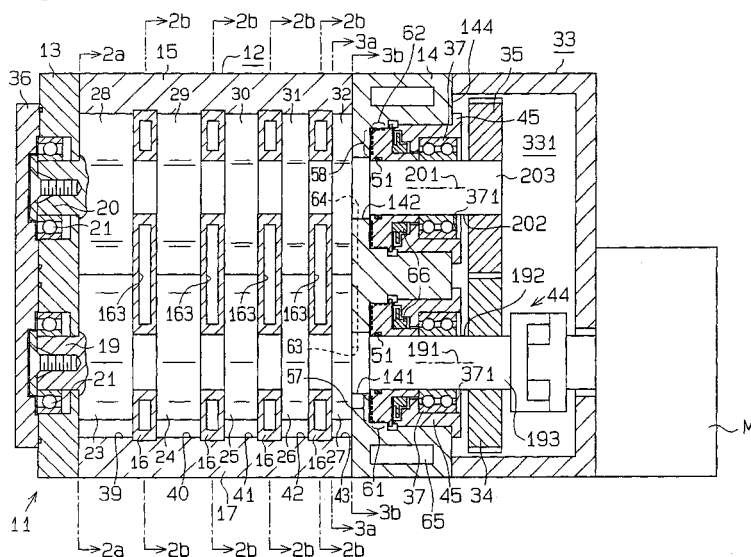
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(54) **Sealing for a rotary vacuum pump**

(57) A Roots pump rotates a plurality of rotors (23-32) by a pair of rotary shafts (19, 20) to draw gas. Each rotary shaft (19, 20) extends through a rear housing member (14) of the Roots pump. A plurality of stoppers (67, 68, 72) are located on each rotary shaft (19, 20) to integrally rotate with the corresponding rotary shaft (19, 20), and prevent oil from entering a fifth pump chamber (43) of the Roots pump. A tapered circumferential surface (671) is located about an axis (191, 201)

of each rotary shaft (19, 20). Each tapered circumferential surface (671) is located adjacent to an end surface (672) of the stopper (67) and is closer to an oil zone (331) than the end surface (672) is. Each tapered circumferential surface (671) is formed such that the distance between the circumferential surface (671) and the axis (191, 201) of the rotary shaft (19, 20) increases from the side closer to the pump chamber (43) to the side closer to the oil zone (331). This effectively prevents oil from entering the pump chamber (43).

Fig.1 (a)



Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to an oil leak prevention structure of a vacuum pump that draws gas by rotating a rotary shaft to move a gas conveying body in a pump chamber.

[0002] Japanese Laid-Open Patent Publication No. 63-129829 and No. 3-11193 each disclose a vacuum pump. The pump of either publication introduces lubricant oil into the interior of the pump. Either pump prevents lubricant oil from entering regions where the oil is not desirable.

[0003] The vacuum pump disclosed in Japanese Laid-Open Patent Publication No. 63-129829 includes a plate attached to a rotary shaft to prevent oil from entering a chamber for an electric generator. Specifically, when moving along the surface of the rotary shaft toward the generator chamber, oil reaches the plate. The centrifugal force of the plate spatters the oil to an annular groove formed about the plate. The oil flows to the lower portion of the annular groove and is then drained to the outside along an oil passage connected to the lower portion.

[0004] The vacuum pump disclosed in Japanese Laid-Open Patent Publication No. 3-11193 has an annular chamber for supplying oil to a bearing and a slinger provided in the annular chamber. When moving along the surface of a rotary shaft from the annular chamber to a vortex flow pump, oil is thrown away by the slinger. The thrown oil is then sent to a motor chamber through a drain hole connected to the annular chamber.

[0005] The plate (slinger) is a mechanism that integrally rotates with a rotary shaft to prevent oil from entering undesirable regions. The oil leak entry preventing operation utilizing centrifugal force of the plate (slinger) is influenced by the shape of the plate (slinger), and the shape of the walls surrounding the plate (slinger).

SUMMARY OF THE INVENTION

[0006] Accordingly, it is an objective of the present invention to provide an oil leak prevention mechanism that effectively prevents oil from entering a pump chamber of a vacuum pump.

[0007] To achieve the foregoing and other objectives and in accordance with the purpose of the present invention, the invention provides a vacuum pump. The vacuum pump draws gas by operating a gas conveying body in a pump chamber through rotation of a rotary shaft. The vacuum pump has an oil housing member, a stopper and a tapered circumferential surface. The oil housing member defines an oil zone adjacent to the pump chamber. The rotary shaft has a projecting section that projects from the pump chamber to the oil zone through the oil housing member. The stopper has an end surface. The stopper is located on the rotary shaft to

integrally rotate with the rotary shaft, and prevents oil from entering the pump chamber. The tapered circumferential surface is located about an axis of the rotary shaft. The tapered circumferential surface is located adjacent to the end surface of the stopper and is closer to the oil zone than the end surface is. The tapered circumferential surface is formed such that the distance between the circumferential surface and the axis of the rotary shaft increases from the side closer to the pump chamber to the side closer to the oil zone.

[0008] Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1(a) is a cross-sectional plan view illustrating a multiple-stage Roots pump according to a first embodiment of the present invention;

Fig. 1(b) is an enlarged partial cross-sectional view of the pump shown in Fig. 1(a);

Fig. 2(a) is a cross-sectional view taken along line 2a-2a in Fig. 1(a);

Fig. 2(b) is a cross-sectional view taken along line 2b-2b in Fig. 1(a);

Fig. 3(a) is a cross-sectional view taken along line 3a-3a in Fig. 1(a);

Fig. 3(b) is a cross-sectional view taken along line 3b-3b in Fig. 1(a);

Fig. 4(a) is a cross-sectional view taken along line 4a-4a in Fig. 3(b);

Fig. 4(b) is an enlarged cross-sectional view of Fig. 4(a);

Fig. 5(a) is a cross-sectional view taken along line 5a-5a in Fig. 3(b);

Fig. 5(b) is an enlarged cross-sectional view of Fig. 5(a);

Fig. 6(a) is an enlarged cross-sectional view of the pump shown in Fig. 1(a);

Fig. 6(b) is an enlarged cross-sectional view of Fig. 6(a);

Fig. 7 is an exploded perspective view illustrating part of the rear housing member, the first shaft seal, and a leak prevention ring of the pump shown in Fig. 1(a);

Fig. 8 is an exploded perspective view illustrating part of the rear housing member, the second shaft seal, and a leak prevention ring of the pump shown in Fig. 1(a);

Fig. 9 is an enlarged cross-sectional view illustrating

ing a second embodiment of the present invention;
and

Fig. 10 is an enlarged cross-sectional view illustrating a third embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] A multiple-stage Roots pump 11 according to a first embodiment of the present invention will now be described with reference to Figs. 1(a) to 8.

[0011] As shown in Fig. 1(a), the pump 11, which is a vacuum pump, includes a rotor housing member 12, a front housing member 13, and a rear housing member 14. The front housing member 13 is coupled to the front end of the rotor housing member 12. A lid 36 closes the front opening of the front housing member 13. The rear housing member 14 is coupled to the rear end of the rotor housing member 12. The rotor housing member 12 includes a cylinder block 15 and chamber defining walls 16, the number of which is four in this embodiment. As shown in Fig. 2(b), the cylinder block 15 includes a pair of blocks 17, 18. Each chamber defining wall 16 includes a pair of wall sections 161, 162.

[0012] As shown in Fig. 1(a), a first pump chamber 39 is defined between the front housing member 13 and the leftmost chamber defining wall 16. Second, third, and fourth pump chambers 40, 41, 42 are each defined between two adjacent chamber defining walls 16 in this order from the left to the right as viewed in the drawing. A fifth pump chamber 43 is defined between the rear housing member 14 and the rightmost chamber defining wall 16.

[0013] A first rotary shaft 19 is rotatably supported by the front housing member 13 and the rear housing member 14 with a pair of radial bearings 21, 37. Likewise, a second rotary shaft 20 is rotatably supported by the front housing member 13 and the rear housing member 14 with a pair of radial bearings 21, 37. The first and second rotary shafts 19, 20 are parallel with each other and extend through the chamber defining walls 16. The radial bearings 37 are supported by bearing holders 45 that are installed in the rear housing member 14. The bearing holders 45 are fitted in first and second recesses 47, 48 that are formed in the rear side of the rear housing member 14, respectively.

[0014] First, second, third, fourth, and fifth rotors 23, 24, 25, 26, 27 are formed integrally with the first rotary shaft 19. Likewise, first, second, third, fourth, and fifth rotors 28, 29, 30, 31, 32 are formed integrally with the second rotary shaft 20. As viewed in the direction along the axes 191, 201 of the rotary shafts 19, 20, the shapes and the sizes of the rotors 23-32 are identical. However, the axial dimensions of the first to fifth rotors 23-27 of the first rotary shaft 19 become gradually smaller in this order. Likewise, the axial dimensions of the first to fifth rotors 28-32 of the second rotary shaft 20 become gradually smaller in this order.

[0015] The first rotors 23, 28 are accommodated in the first pump chamber 39 and are engaged with each other. The second rotors 24, 29 are accommodated in the second pump chamber 40 and are engaged with each other. The third rotors 25, 30 are accommodated in the third pump chamber 41 and are engaged with each other. The fourth rotors 26, 31 are accommodated in the fourth pump chamber 42 and are engaged with each other. The fifth rotors 27, 32 are accommodated in the fifth pump chamber 43 and are engaged with each other. The first to fifth pump chambers 39-43 are not lubricated. Thus, the rotors 23-32 are arranged not to contact any of the cylinder block 15, the chamber defining walls 16, the front housing member 13, and the rear housing member 14. Further, the rotors of each engaged pair do not slide against each other.

[0016] As shown in Fig. 2(a), the first rotors 23, 28 define a suction zone 391 and a pressure zone 392 in the first pump chamber 39. The pressure in the pressure zone 392 is higher than the pressure in the suction zone 391. Likewise, the second to fourth rotors 24-26, 29-31 define suction zones and pressure zones in the associated pump chambers 40-42. As shown in Fig. 3(a), the fifth rotors 27, 32 define a suction zone 431 and a pressure zone 432, which are similar to the suction zone 391 and the pressure zone 392, in the fifth pump chamber 43.

[0017] As shown in Fig. 1(a), a gear housing member 33 is coupled to the rear housing member 14. A pair of through holes 141, 142 is formed in the rear housing member 14. The rotary shafts 19, 20 extend through the through holes 141, 142 and the first and second recesses 47, 48, respectively. The rotary shafts 19, 20 thus project into the gear housing member 33 to form projecting portions 193, 203, respectively. Gears 34, 35 are secured to the projecting portions 193, 203, respectively, and are meshed together. An electric motor M is connected to the gear housing member 33. A shaft coupling 44 transmits the drive force of the motor M to the first rotary shaft 19. The motor M thus rotates the first rotary shaft 19 in the direction indicated by arrow R1 of Figs. 2(a) to 3(b). The gears 34, 35 transmit the rotation of the first rotary shaft 19 to the second rotary shaft 20. The second rotary shaft 20 thus rotates in the direction indicated by arrow R2 of Figs. 2(a) to 3(b). Accordingly, the first and second rotary shafts 19, 20 rotate in opposite directions. The gears 34, 35 form a gear mechanism to rotate the rotary shafts 19, 20 integrally.

[0018] As shown in Figs. 4(a) and 5(a), a gear accommodating chamber 331 is formed in the gear housing member 33 and retains lubricant oil Y for lubricating the gears 34, 35. The gear accommodating chamber 331 and the recesses 47, 48 form a sealed oil zone. The gear housing member 33 and the rear housing member 14 thus form an oil housing, or an oil zone adjacent to the fifth pump chamber 43. The gears 34, 35 rotate to lift the lubricant oil Y in the gear accommodating chamber 331. The lubricant oil Y thus lubricates the radial bearings 37.

[0019] As shown in Figs. 1(a) and 2(b), a hollow 163 is defined in each chamber defining wall 16. Each chamber defining wall 16 has an inlet 164 and an outlet 165 that are connected to the hollow 163. Each adjacent pair of the pump chambers 39-43 are connected to each other by the hollow 163 of the associated chamber defining wall 16.

[0020] As shown in Fig. 2(a), an inlet 181 is formed in the block 18 of the cylinder block 15 and is connected to the suction zone 391 of the first pump chamber 39. As shown in Fig. 3(a), an outlet 171 is formed in the block 17 of the cylinder block 15 and is connected to the pressure zone 432 of the fifth pump chamber 43. When gas enters the suction zone 391 of the first pump chamber 39 from the inlet 181, rotation of the first rotors 23, 28 moves the gas to the pressure zone 392. The gas is compressed in the pressure zone 392 and enters the hollow 163 of the adjacent chamber defining wall 16 from the inlet 164. The gas then reaches the suction zone of the second pump chamber 40 from the outlet 165 of the hollow 163. Afterwards, the gas flows from the second pump chamber 40 to the third, fourth, and fifth pump chambers 41, 42, 43 in this order while repeatedly compressed. The volumes of the first to fifth pump chambers 39-43 become gradually smaller in this order. When the gas reaches the suction zone 431 of the fifth pump chamber 43, rotation of the fifth rotors 27, 32 moves the gas to the pressure zone 432. The gas is then discharged from the outlet 171 to the exterior of the vacuum pump 11. That is, each rotor 23-32 functions as a gas conveying body for conveying gas.

[0021] The outlet 171 functions as a discharge passage for discharging gas to the exterior of the vacuum pump 11. The fifth pump chamber 43 is a final-stage pump chamber that is connected to the outlet 171. Among the pressure zones of the first to fifth pump chambers 39-43, the pressure in the pressure zone 432 of the fifth pump chamber 43 is the highest, and the pressure zone 432 functions as a maximum pressure zone.

[0022] As shown in Figs. 4(a) and 5(a), first and second annular shaft seals 49, 50 are securely fitted about the first and second rotary shafts 19, 20, respectively, and are located in the first and second recesses 47, 48, respectively. Each of the first and second shaft seals 49, 50 rotates with the corresponding rotary shaft 19, 20. A seal ring 51 is located between the inner circumferential surface of each of the first and second shaft seals 49, 50 and the circumferential surface 192, 202 of the corresponding rotary shaft 19, 20. Each seal ring 51 prevents the lubricant oil Y from leaking from the associated recess 47, 48 to the fifth pump chamber 43 along the circumferential surface 192, 202 of the associated rotary shaft 19, 20.

[0023] As shown in Fig. 4(a), the shaft seal 49 includes a small diameter portion 59 and a large diameter portion 60. As shown in Fig. 4(b), space exists between the outer circumferential surface 491 of the large diameter portion 60 and the circumferential surface 471 of

the first recess 47. Also, space exists between the end surface 492 of the first shaft seal 49 and the bottom 472 of the first recess 47. As shown in Fig. 5(a), the second shaft seal 50 includes a small diameter portion 81 and a large diameter portion 80. As shown in Fig. 5(b), space exists between the circumferential surface 501 of the large diameter portion 80 and the circumferential surface 481 of the second recess 48. Also, space exists between the end surface 502 of the second shaft seal 50 and the bottom 482 of the second recess 48.

[0024] Annular projections 53 coaxially project from the bottom 472 of the first recess 47. In the same manner, annular projections 54 coaxially project from the bottom 482 of the second recess 48. Further, annular grooves 55 are coaxially formed in the end surface 492 of the shaft seal 49, which faces the bottom 472 of the first recess 47. In the same manner, annular grooves 56 are coaxially formed in the end surface 502 of the shaft seal 50, which faces the bottom 482 of the second recess 48. Each annular projection 53, 54 projects in the associated groove 55, 56 such that the distal end of the projection 53, 54 is located close to the bottom of the groove 55, 56. Each projection 53 divides the interior of the associated groove 55 of the first shaft seal 49 to a pair of labyrinth chambers 551, 552. Each projection 54 divides the interior of the associated groove 56 of the second shaft seal 50 to a pair of labyrinth chambers 561, 562.

[0025] The projections 53 and the grooves 55 form a first labyrinth seal 57 corresponding to the first rotary shaft 19. The projections 54 and the grooves 56 form a second labyrinth seal 58 corresponding to the second rotary shaft 20. In this embodiment, the end surface 492 and the bottom 472 are formed along a plane perpendicular to the axis 191 of the first rotary shaft 19. Likewise, the end surface 502 and the bottom 482 are formed along a plane perpendicular to the axis 201 of the rotary shaft 20. In other words, the end surface 492 and the bottom 472 are seal forming surfaces that extend in a radial direction of the first shaft 19. Likewise, the end surface 502 and the bottom 482 are seal forming surfaces that extend in a radial direction of the second shaft 50.

[0026] As shown in Figs. 4(b) and 7, a first helical groove 61 is formed in the outer circumferential surface 491 of the large diameter portion 60 of the first shaft seal 49. As shown in Figs. 5(b) and 8, a second helical groove 62 is formed in the outer circumferential surface 501 of the large diameter portion 80 of the second shaft seal 50. Along the rotational direction R1 of the first rotary shaft 19, the first helical groove 61 forms a path that leads from a side corresponding to the gear accommodating chamber 331 toward the fifth pump chamber 43. Along the rotational direction R2 of the second rotary shaft 20, the second helical groove 62 forms a path that leads from a side corresponding to the gear accommodating chamber 331 toward the fifth pump chamber 43. Therefore, each helical groove 61, 62 exert a pumping

effect and convey fluid from a side corresponding to the fifth pump chamber 43 toward the gear accommodating chamber 331 when the rotary shafts 19, 20 rotate. That is, each helical groove 61, 62 forms pumping means that urges the lubricant oil Y between the outer circumferential surface 491, 501 of the associated shaft seal 49, 50 and the circumferential surface 471, 481 of the associated recess 47, 48 to move from a side corresponding to the fifth pump chamber 43 toward the oil zone.

[0027] As shown in Fig. 3(b), first and second discharge pressure introducing channels 63, 64 are formed in a chamber defining surface 143 of the rear housing member 14. The chamber defining surface 143 defines the fifth pump chamber 43, which is at the final stage of compression. As shown in Fig. 4(a), the first discharge pressure introducing channel 63 is connected to the maximum pressure zone 432, the volume of which is varied by rotation of the fifth rotors 27, 32. The first discharge pressure introducing channel 63 is connected also to the through hole 141, through which the first rotary shaft 19 extends. As shown in Fig. 5(a), the second discharge pressure introducing channel 64 is connected to the maximum pressure zone 432 and the through hole 142, through which the second rotary shaft 20 extends.

[0028] As shown in Figs. 1(a), 4(a), and 5(a), a cooling loop chamber 65 is formed in the rear housing member 14. The loop chamber 65 surrounds the shaft seals 49, 50. Coolant water circulates in the loop chamber 65 to cool the lubricant oil Y in the recesses 47, 48, which prevents the lubricant oil Y from evaporating.

[0029] As shown in Figs. 1(b), 6(a) and 6(b), an annular leak prevention ring 66 is fitted about the small diameter portion 59 of the first shaft seal 49 to block flow of oil. The leak prevention ring 66 includes a first stopper 67 having a smaller diameter and a second stopper 68 having a larger diameter. A front end portion of the bearing holder 45 has an annular projection projecting inward and defines an annular first oil chamber 70 and an annular second oil chamber 71 about the leak prevention ring 66. The centers of the first oil chamber 70 and the second oil chamber 71 coincide with the axis 191 of the rotary shaft 19. The first oil chamber 70 surrounds the first stopper 67, and the second oil chamber 71 surrounds the second stopper 68.

[0030] A circumferential surface 671 of the first stopper 67 is tapered, or inclined with respect to the axis 191 of the first rotary shaft 19. Specifically, the tapered circumferential surface 671 is formed such that the distance between the axis 191 and the tapered circumferential surface 671 decreases from the side closer to the gear chamber 331 toward the fifth pump chamber 43. The tapered circumferential surface 671 is located in the first oil chamber 70. A circumferential surface 681 of the second stopper 68 is located in the second oil chamber 71. The tapered circumferential surface 671 of the first stopper 67 faces a circumferential surface 702, which defines the first oil chamber 70. The circumferential surface 681 of the second stopper 68 faces a circumferen-

tial surface 712, which defines the second oil chamber 71.

[0031] An end surface 672 of the first stopper 67 faces an end surface 701, which defines the first oil chamber 70. A first end surface 682 of the second stopper 68 faces and is located in the vicinity of an end surface 711, which defines the second oil chamber 71. A second end surface 683 of the second stopper 68 faces and is widely separated from a first end surface 601 of a third stopper 72. The third stopper 72 will be discussed below.

[0032] The first end surface 682 of the second stopper 68 is perpendicular to the axis 191 of the first rotary shaft 19. The first end surface 682 prevents the lubricant oil Y from entering the fifth pump chamber 43. The tapered circumferential surface 671 of the first stopper 67 is located adjacent to the first end surface 682 and is closer to the gear accommodating chamber 331 than the first end surface 682. The tapered circumferential surface 671 extends from the proximal end 684 of the first end surface 682. A plane formed by extending the tapered circumferential surface 671 toward the end surface intersects the end surface 701 of the first oil chamber 70.

[0033] The third stopper 72 is integrally formed with the large diameter portion 60 of the first shaft seal 49. An annular oil chamber 73 is defined in the first recess 47 to surround the third stopper 72. A circumferential surface 721 of the third stopper 72 is defined on a portion that projects into the third oil chamber 73. Also, the circumferential surface 721 of the third stopper 72 faces a circumferential surface 733 defining the third oil chamber 73. The first end surface 601 of the third stopper 72 faces and is located in the vicinity of a first end surface 731 defining the third oil chamber 73. A second end surface 722 of the third stopper 72 faces and is located in the vicinity of a second end surface 732 defining the third oil chamber 73.

[0034] A drainage channel 74 is defined in the lowest portion of the first recess 47 and the end 144 of the rear housing 14 to return the oil Y to the gear accommodation chamber 331. The drainage channel 74 has an axial portion 741, which extends along the axis 191 of the first rotary shaft 19, and a radial portion 742, which extends perpendicular to the axis 191. The axial portion 741 is communicated with the third oil chamber 73, and the radial portion 742 is communicated with the gear accommodation chamber 331. That is, the third oil chamber 73 is connected to the gear accommodating chamber 331 by the drainage channel 74. In this embodiment, the drainage channel 74 extends horizontally. Alternatively, the channel 74 may be inclined downward toward the gear accommodation chamber 331.

[0035] As shown in Fig. 5(a), a leak prevention ring 66 is attached to the small diameter portion 81 of the second shaft seal 50. Since the leak prevention ring 66 has the same structure as the ring 66 attached to the first shaft seal 49, the description thereof is omitted. A third stopper 72 is formed on the large diameter portion 80 of the second shaft seal 50. The third stopper 72 has

the same structure as the third stopper 72 attached to the first shaft seal 49, the description thereof is omitted. As shown in Fig. 5(b), the first and second oil chambers 70, 71 are defined radially inward of the bearing holder 45, and the third oil chamber 73 is defined in the second recess 48. The drainage channel 74 is formed in the lowest portion of the second recess 48. The third oil chamber 73 is connected to the gear accommodating chamber 331 through the drainage channel 74. In this embodiment, the drainage channel 74 extends horizontally. Alternatively, the channel 74 may be inclined downward toward the gear accommodation chamber 331.

[0036] The lubricant oil Y stored in the gear accommodating chamber 331 lubricates the gears 34, 35 and the radial bearings 37. After lubricating the radial bearings 37, the oil Y enters a through hole 691 formed in the front end portion 69 of each bearing holder 45 through a space 371 in each radial bearing 37. Then, the oil Y moves toward the corresponding first oil chamber 70 via a space g1 between the end surface 672 of the corresponding first stopper 67 and the end surface 701 of the corresponding first oil chamber 70. At this time, some of the oil Y that reaches the end surface 672 of the first stopper 67 is thrown to the circumferential surface 702 or the end surface 701 of the first oil chamber 70 by the centrifugal force generated by rotation of the first stopper 67. At least part of the oil Y thrown to the circumferential surface 702 or the end surface 701 remains on the circumferential surface 702 or the end surface 701. Then, the remaining oil Y falls along the surfaces 701, 702 by the self weight and reaches the lowest area of the first oil chamber 70. After reaching the lowest area of the first oil chamber 70, the oil Y moves to the lowest area of the second oil chamber 71.

[0037] After entering the first oil chamber 70, the oil Y moves toward the second oil chamber 71 through a space g2 between the first end surface 682 of the second stopper 68 and the end surface 711 of the second oil chamber 71. At this time, the oil Y on the first end surface 682 is thrown to the circumferential surface 712 or the end surface 711 of the second oil chamber 71 by the centrifugal force generated by rotation of the second stopper 68. At least part of the oil Y thrown to the circumferential surface 712 or the end surface 711 remains on the circumferential surface 712 or the end surface 711. The remaining oil Y falls along the surfaces 711, 712 by the self weight and reaches the lowest area of the second oil chamber 71.

[0038] Above each rotary shaft 19, 20, the oil Y is thrown from the end surface 672 of the corresponding first stopper 67 to the circumferential surface 702 or the end surface 701 of the corresponding first oil chamber 70. Some of the oil Y may drop onto the tapered circumferential surface 671 of the first stopper 67. The oil Y is also thrown from the first end surface 682 of the second stopper 68 to the circumferential surface 712 or the end surface 711 of the second oil chamber 71. Some of the oil Y may drop onto the tapered circumferential surface

671. Some of the oil Y that has dropped onto the tapered circumferential surface 671 is either thrown to the circumferential surface 702 of the first oil chamber 70 by the centrifugal force generated by rotation of the leak prevention ring 66 or moved to the end surface 701 of the first oil chamber 70 from the first end surface 682 of the second stopper 68 along the tapered circumferential surface 671. When moving from the first end surface 682 to the end surface 701 along the tapered circumferential surface 671, the oil Y is thrown to the end surface 701 or moves to the end surface 672 of the first stopper 67. In this manner, the oil Y on the tapered circumferential surface 671 eventually reaches the second oil chamber 71. After reaching the lowest area of the second oil chamber 71, the lubricant oil Y flows to the lowest area of the third oil chamber 73.

[0039] After reaching the lowest part of each second oil chamber 71, the oil Y moves to the lowest area of the corresponding third oil chamber 73.

[0040] After entering the second oil chamber 71, the oil Y moves toward the third oil chamber 73 through the space g3 between the first end surface 601 of the third stopper 72 and the first end surface 731 of the third oil chamber 73. At this time, the oil Y on the first end surface 601 is thrown to the circumferential surface 733 or the first end surface 731 of the third oil chamber 73 by the centrifugal force generated by rotation of the third stopper 72. At least part of the oil thrown to the circumferential surface 733 or the first end surface 731 remains on the circumferential surface 733 or the first end surface 731. Then, the remaining oil falls along the corresponding surface 731, 733 by the self-weight and reaches the lowest area of the third oil chamber 73.

[0041] After reaching the lowest area of the third oil chamber 73, the oil Y is returned to each gear accommodating chamber 331 by the corresponding drainage channel 74.

[0042] The above illustrated embodiment has the following advantages.

[0043] (1-1) While the vacuum pump is operating, the pressures in the five pump chambers 39, 40, 41, 42, 43 are lower than the pressure in the gear accommodating chamber 331, which is a zone exposed to the atmospheric pressure. Thus, the lubricant oil Y moves along the surface of the leak prevention rings 66 and the surface of the shaft seals 49, 50 toward the fifth pump chamber 43. When on the first end surface 682 of each second stopper 68, the oil Y is thrown radially by the centrifugal force generated by rotation of the corresponding leak prevention ring 66. At least part of the oil Y that is thrown from the first end surface 682 and drops on the tapered circumferential surface 671 of the first stopper 67 is moved from a smaller diameter portion to a larger diameter portion of the tapered circumferential surface 671 by the centrifugal force generated by rotation of the leak prevention ring 66. In other words, the oil Y is moved away from the fifth pump chamber 43. As a result, the oil Y is prevented from entering the fifth

pump chamber 43. That is, since the tapered circumferential surface 671 is located adjacent to the first end surface 682, the lubricant oil Y is prevented from moving toward the fifth pump chamber 43.

[0044] (1-2) The smallest diameter portion of the tapered circumferential surface 671 of each first stopper 67 is directly connected to the proximal end 684 of the first end surface 682 of the corresponding second stopper 68. If a circumferential surface of a constant diameter is connected to the proximal end 684 of the first end surface 682, part of the lubricant oil Y that is thrown from the first end surface 682 may return to the first end surface 682 after staying on the circumferential surface. The structure with the flat surface is not suitable for preventing oil from entering the fifth pump chamber 43. However, in the above illustrated embodiment, since the tapered circumferential surface 671 is directly connected to the first end surface 682, the oil Y that is thrown from the first end surface 682 is prevented from returning to the first end surface 682.

[0045] (1-3) Lubricant oil Y on the surfaces 701, 702, 711, 712, 731, 732, 733 of the first, second, and third oil chambers 70, 71, 73 falls toward the lowest area of the third oil chamber 73 by the self weight. The lowest area of the third oil chamber 73 is an area at which the oil Y on the surfaces 701, 702, 711, 712, 731, 732, 733 is collected. Therefore, the oil Y on the surfaces 701, 702, 711, 712, 731, 732, 733 is readily sent to the gear accommodating chamber 331 via the drainage channel 74 connected to the lowest area of the third oil chamber 73.

[0046] (1-4) The diameters of the end surfaces 492, 502 of the shaft seals 49, 50 fitted about the first and second rotary shafts 19, 20 are greater than the diameters of the circumferential surfaces 192, 202 of the rotary shafts 19, 20. Therefore, the diameter of each of the first and second labyrinth seals 57, 58 located between the end surface 492, 502 of each shaft seal 49, 50 and the bottom surface 472, 482 of the corresponding recess 47, 48 is greater than the diameter of the labyrinth seal (not shown) located between the circumferential surface 192, 202 of each rotary shaft 19, 20 and the through hole 141, 142. As the diameter of each labyrinth seal 57, 58 is increased, the volume of each labyrinth chamber 551, 552, 561, 562 for preventing pressure fluctuations from spreading is increased. This structure improves the sealing performance of each labyrinth seal 57, 58. That is, the space between the end surface 492, 502 of each shaft seal 49, 50 and the bottom surface 472, 482 of the associated recess 47, 48 is suitable for accommodating the labyrinth seal 57, 58 for improving the sealing performance by increasing the volume of each labyrinth chamber 551, 552, 561, 562.

[0047] (1-5) As the space between each recess 47, 48 and the corresponding shaft seal 49, 50 is decreased, it is harder for the oil Y to enter the space. The bottom surface 472, 482 of each recess 47, 48, which has the circumferential surface 471, 481, and the end surface 492, 502 of the corresponding shaft seal 49, 50

are easily formed to be close to each other. Therefore, the space between the end of each annular projection 53, 54 and the bottom of the corresponding annular groove 55, 56 and the space between the bottom surface 472, 482 of each recess 47, 48 and the end surface 492, 502 of the corresponding shaft seal 49, 50 can be easily decreased. As the spaces are decreased, the sealing performance of the labyrinth seals 57, 58 is improved. That is, the bottom surface 472, 482 of each recess 47, 48 is suitable for accommodating the labyrinth seals 57, 58.

[0048] (1-6) The labyrinth seals 57, 58 exerts a sufficient sealing performance against gas. When the Roots pump 11 is started, the pressures in the five pump chambers 39-43 are higher than the atmospheric pressure. However, each labyrinth seal 57, 58 prevents gas from leaking from the fifth pump chamber 43 to the gear accommodating chamber 331 along the surface of the associated shaft seal 49, 50. That is, the labyrinth seals 57, 58 stop both oil leak and gas leak and are optimal non-contact type seals.

[0049] (1-7) Although the sealing performance of a non-contact type seal does not deteriorate over time unlike a contact type seal such as a lip seal, the sealing performance of a non-contact type seal is inferior to the sealing performance of a contact type seal. However, in the above described embodiment, the first, second and third stoppers 67, 68, 72 compensate for the sealing performance. The inclined tapered circumferential surface 671 is formed on each leak prevention ring 66 to be adjacent to the first end surface 682 of the corresponding second stopper 68. The tapered circumferential surface 671 further reliably compensates for the sealing performance.

[0050] (1-8) As the first rotary shaft 19 rotates, the oil Y in the first helical groove 61 is guided from the side corresponding to the fifth pump chamber 43 to the side corresponding to the gear accommodating chamber 331. As the second rotary shaft 20 rotates, the oil Y in the second helical groove 62 is guided from the side corresponding to the fifth pump chamber 43 to the side corresponding to the gear accommodating chamber 331. That is, the shaft seals 49, 50, which have the first and second helical grooves 61, 62 functioning as pumping means, positively prevent leakage of the oil Y.

[0051] (1-9) The circumferential surfaces 491, 501, on which the helical grooves 61, 62 are formed, coincide with the outer surface of the large diameter portions 60, 80 of the first and second shafts 49, 50. At these parts, the velocity is maximum when the shaft seals 49, 50 rotate. Gas located between the outer circumferential surface 491, 501 of each shaft seal 49, 50 and the circumferential surface 471, 481 of the associated recess 47, 48 is effectively urged from the side corresponding to the fifth pump chamber 43 to the side corresponding to the gear accommodating chamber 331 through the first and second helical grooves 61, 62, which are moving at a high speed. The lubricant oil Y located between the

outer circumferential surface 491, 501 of each shaft seal 49, 50 and the circumferential surface 471, 481 of the associated recess 47, 48 flows with gas that is effectively urged from the side corresponding to the fifth pump chamber 43 to the side corresponding to the gear accommodating chamber 331. The helical grooves 61, 62 formed in the outer circumferential surface 491, 501 of the shaft seals 49, 50 effectively prevent the oil Y from leaking into the fifth pump chamber 43 from the recesses 47, 48 via the spaces between the outer surfaces 491, 501 and the circumferential surfaces 471, 481.

[0052] (1-10) A small space is created between the circumferential surface 192 of the first rotary shaft 19 and the through hole 141. Also, a small space is created between each rotor 27, 32 and the wall forming surface 143 of the rear housing member 14. Therefore, the labyrinth seal 57 is exposed to the pressure in the fifth pump chamber 43 introduced through the narrow spaces. Likewise, a small space is created between the circumferential surface 202 of the second rotary shaft 20 and the through hole 142. Therefore, the second labyrinth seal 58 is exposed to the pressure in the fifth pump chamber 43 through the space. If there are no channels 63, 64, the labyrinth seals 57, 58 are equally exposed to the pressure in the suction pressure zone 431 and to the pressure in the maximum pressure zone 432.

[0053] The first and second discharge pressure introducing channels 63, 64 readily expose the labyrinth seals 57, 58 to the pressure in the maximum pressure zone 432. That is, the labyrinth seals 57, 58 are influenced more by the pressure in the maximum pressure zone 432 via the introducing channels 63, 64 than by the pressure in the suction pressure zone 431. Thus, compared to a case where no discharge pressure introducing channels 63, 64 are formed, the labyrinth seals 57, 58 of the illustrated embodiment receive higher pressure. As a result, compared to a case where no discharge pressure introducing channels 63, 64 are formed, the difference between the pressure acting on the front surface of the labyrinth seals 57, 58 and the pressure acting on the rear surface of the labyrinth seals 57, 58 is significantly small. In other words, the discharge pressure introducing channels 63, 64 significantly improves the oil leakage preventing performance of the labyrinth seals 57, 58.

[0054] (1-11) Since the Roots pump 11 is a dry type, no lubricant oil Y is used in the five pump chambers 39, 40, 41, 42, 43. Therefore, the present invention is suitable for the Roots pump 11.

[0055] A second embodiment according to the present invention will now be described with reference to Fig. 9. Mainly, the differences from the embodiment of Figs. 1 to 8 will be discussed below. Since the first and second rotary shafts 19, 20 have the same sealing structure, only the sealing structure of the first rotary shaft 19 will be described.

[0056] As shown in Fig. 9, a leakage prevention ring 66 of the second embodiment has an inclined circum-

ferential surface 75 formed between the second stopper 68 and the end surface 601 of the large diameter portion 60. The diameter of the circumferential surface 75 increases from the end surface 601 of the large diameter portion 60 to the second stopper 68. When thrown from the end surfaces 601, 683 to the circumferential surface 75, the oil Y is moved from the end surface 601 to the end surface 683 by the centrifugal force generated by rotation of the leak prevention ring 66. The circumferential surface 75 has the same functions as the tapered circumferential surface 671 of the embodiment illustrated in Figs. 1 to 8. The end surface 601 functions as oil leakage prevention surface that corresponds to the circumferential surface 75.

[0057] A third embodiment according to the present invention will now be described with reference to Fig. 10. Since the first and second rotary shafts 19, 20 have the same sealing structure, only the sealing structure of the first rotary shaft 19 will be described. In this embodiment, a shaft seal 49A is integrally formed with an end of the first rotary shaft 19 and an end of the rotor 27. The shaft seal 49A is located in a third recess 76, which is formed in an end surface of the rear housing member 14 that faces the rotor housing member 12. A labyrinth seal 77 is located between the surface of the shaft seal 49A and the bottom surface 761 of the recess 76.

[0058] A leak prevention ring 78 is attached to the first rotary shaft 19. An annular oil chamber 79 is defined between the inner bottom surface 472 of the first recess 47 and a projection 169 of the bearing holder 45. The prevention ring 78 is located in the oil chamber 79.

[0059] The prevention ring 78 includes an inclined surface 781 and an end surface 782. The inclined surface 781 has the same functions as the tapered circumferential surface 671 of the embodiment shown in Figs. 1 to 8 and the circumferential surface 75 of the embodiment of Fig. 9.

[0060] The illustrated embodiments may be modified as follows.

(1) In the embodiment shown in Figs. 1 to 8, each shaft seal 49, 50 may be integrally formed with the corresponding leak prevention ring 66.

(2) In the embodiment of Figs. 1 to 8, the end surface 672 of each first stopper 67 may function as an oil entry prevention surface, and an inclined surface connected to the end surface 672 may be formed on the circumferential surface 192, 202 of each rotary shaft 19, 20.

(3) The present invention may be applied to other types of vacuum pumps than Roots pumps.

[0061] Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope

and equivalence of the appended claims.

[0062] A Roots pump rotates a plurality of rotors (23-32) by a pair of rotary shafts (19, 20) to draw gas. Each rotary shaft (19, 20) extends through a rear housing member (14) of the Roots pump. A plurality of stoppers (67, 68, 72) are located on each rotary shaft (19, 20) to integrally rotate with the corresponding rotary shaft (19, 20), and prevent oil from entering a fifth pump chamber (43) of the Roots pump. A tapered circumferential surface (671) is located about an axis (191, 201) of each rotary shaft (19, 20). Each tapered circumferential surface (671) is located adjacent to an end surface (672) of the stopper (67) and is closer to an oil zone (331) than the end surface (672) is. Each tapered circumferential surface (671) is formed such that the distance between the circumferential surface (671) and the axis (191, 201) of the rotary shaft (19, 20) increases from the side closer to the pump chamber (43) to the side closer to the oil zone (331). This effectively prevents oil from entering the pump chamber (43).

Claims

1. A vacuum pump that draws gas by operating a gas conveying body (23-32) in a pump chamber (39-43) through rotation of a rotary shaft (19, 20), the vacuum pump being **characterized by**:
 - an oil housing member (14, 33), wherein the oil housing member (14, 33) defines an oil zone (331) adjacent to the pump chamber (39-43), and the rotary shaft (19, 20) has a projecting section that projects from the pump chamber (39-43) to the oil zone (331) through the oil housing member (14, 33);
 - a stopper (67, 68, 72, 78) having an end surface (672, 681, 682, 683, 601, 721, 722, 782), wherein the stopper (67, 68, 72, 78) is located on the rotary shaft (19, 20) to integrally rotate with the rotary shaft (19, 20), and prevents oil from entering the pump chamber (39-43); and
 - a tapered circumferential surface (671, 781, 75) located about an axis (191, 201) of the rotary shaft (19, 20), wherein the tapered circumferential surface (671, 781, 75) is located adjacent to the end surface (672, 681, 682, 683, 601, 721, 722, 782) of the stopper (67, 68, 72, 78) and is closer to the oil zone (331) than the end surface (672, 681, 682, 683, 601, 721, 722, 782) is, wherein the tapered circumferential surface (671, 781, 75) is formed such that the distance between the circumferential surface (671, 781, 75) and the axis (191, 201) of the rotary shaft (19, 20) increases from the side closer to the pump chamber (39-43) to the side closer to the oil zone (331).
2. The pump according to claim 1, **characterized in that** the tapered circumferential surface (671, 781, 75) is the outer circumferential surface of the stopper (67, 68, 72, 78) and extends from the end surface (672, 681, 682, 683, 601, 721, 722, 782) of the stopper (67, 68, 72, 78).
3. The pump according to claims 1 or 2, further being **characterized by**:
 - an oil chamber (70, 71, 73, 79) surrounding the stopper (67, 68, 72, 78), wherein the center of the oil chamber (70, 71, 73, 79) coincides with the axis (191, 201) of the rotary shaft (19, 20), wherein an end surface (701) that defines the oil chamber (70, 71, 73, 79) intersects a plane formed by extending the tapered circumferential surface (671, 781, 75) toward the end surface (701); and
 - a drainage channel (74) connected to an area at which the oil flowing from the end surface (701, 711, 731, 732) of the oil chamber (70, 71, 73, 79) is collected.
4. The pump according to claim 3, **characterized in that** the drainage channel (74) connects the oil chamber (70, 71, 73, 79) to the oil zone (331) to conduct oil to the oil zone (331).
5. The pump according to claim 4, **characterized in that** the drainage channel (74) is connected to the lowest area of the oil chamber (70, 71, 73, 79).
6. The pump according to claim 5, **characterized in that** the drainage channel (74) is relatively horizontal or is inclined downward toward the oil zone (331).
7. The pump according to any one of claims 1 to 6, **characterized in that** the oil zone (331) accommodates a bearing (37), which rotatably supports the rotary shaft (19, 20).
8. The pump according to any one of claims 1 to 7, further being **characterized by**:
 - an annular shaft seal (49, 50), which is located around the projecting section to rotate integrally with the rotary shaft (19, 20), wherein the shaft seal (49, 50) is located closer to the pump chamber (39-43) than the stopper (67, 68, 72, 78) is and has a first seal forming surface (492, 502) that extends in a radial direction of the shaft seal (49, 50);
 - a second seal forming surface (472, 482) formed on the oil housing member (14, 33), wherein the second seal forming surface (472, 482) faces the first seal forming surface (492, 502).

502) and is substantially parallel with the first seal forming surface (492, 502); and a non-contact type seal (57, 58) located between the first and second seal forming surfaces (492, 502, 472, 482).

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9. The pump according to any one of claims 1 to 8, further being **characterized by**:

a seal surface (471, 481) located on the oil housing (14, 33);
 an annular shaft seal (49, 50), which is located around the projecting section to rotate integrally with the rotary shaft (19, 20), wherein the shaft seal (49, 50) is located closer to the pump chamber (39-43) than the stopper (67, 68, 72, 78) is, wherein the shaft seal (49, 50) includes a pumping means (61, 62) located on a surface of the shaft seal (49, 50) that faces the seal surface (471, 481), wherein the pumping means (61, 62) guides oil between a surface of the shaft seal (49, 50) and the seal surface (471, 481) from the side closer to the pump chamber (39-43) toward the side closer to the oil zone (331).

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10. The vacuum pump according to any one of claims 1 to 9 **characterized in that** the rotary shaft is one of a plurality of parallel rotary shafts (19, 20), a gear mechanism (34, 35) connects the rotary shafts (19, 20) to one another such that the rotary shafts (19, 20) rotate integrally, and the gear mechanism (34, 35) is located in the oil zone (331).

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11. The vacuum pump according to claim 10 **characterized in that** a plurality of rotors (23-32) are formed around each rotary shaft (19, 20) such that each rotor (23-32) functions as the gas conveying body, and the rotors of one rotary shaft are engaged with the rotors of another rotary shaft.

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Fig. 1 (a)

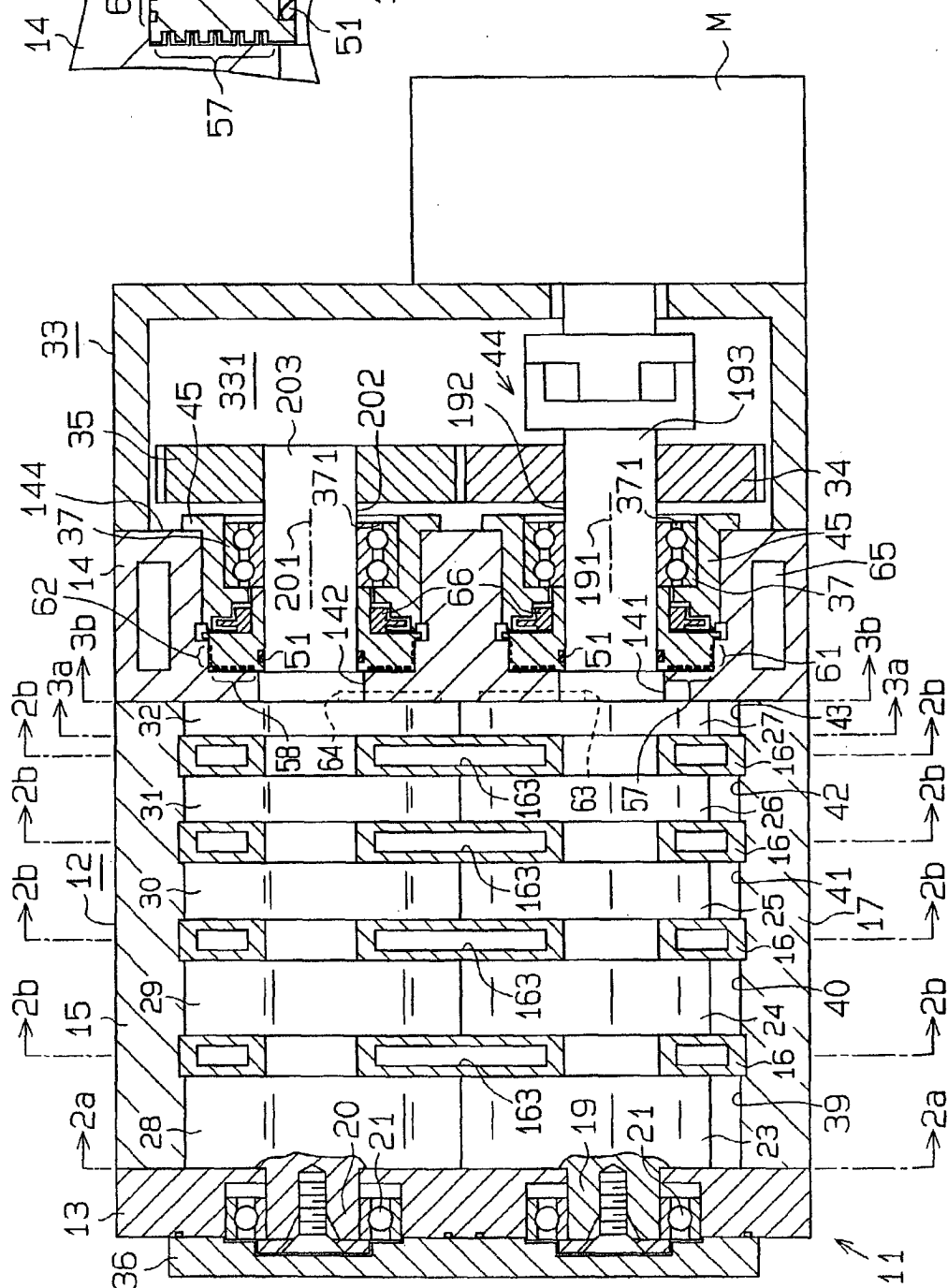


Fig. 1 (b)

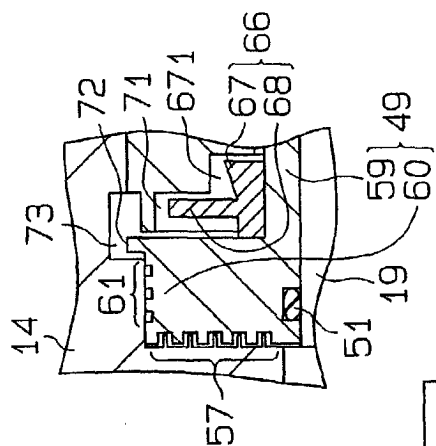


Fig. 2(a)

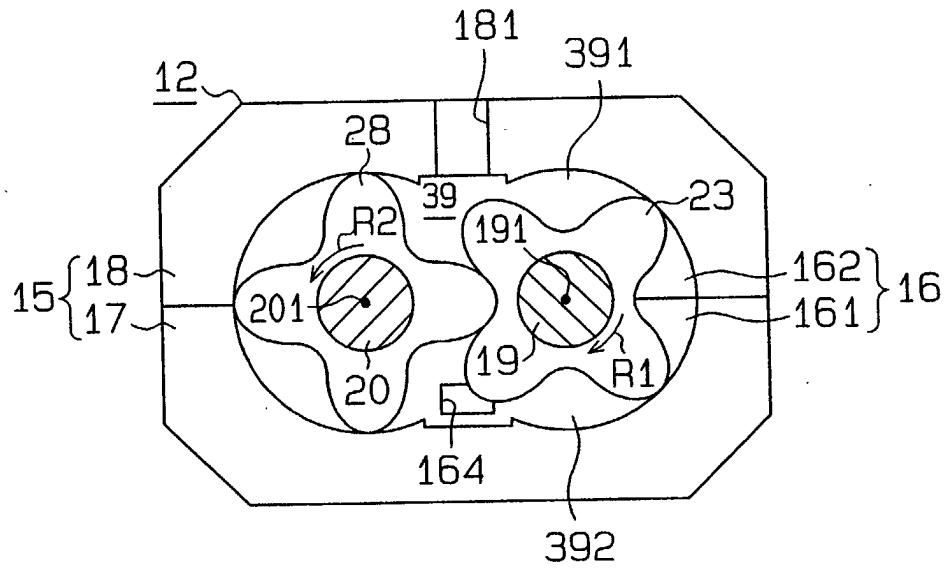


Fig. 2(b)

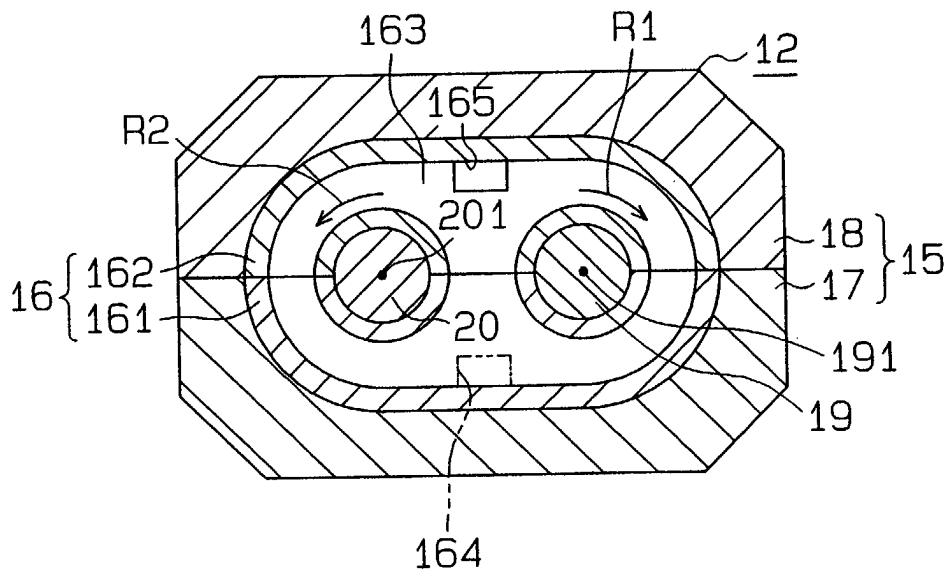


Fig. 3(a)

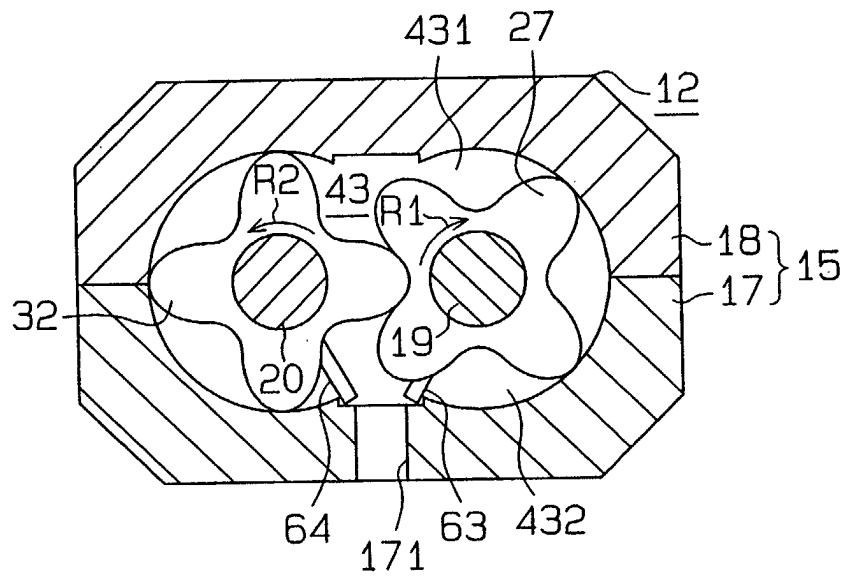


Fig. 3(b)

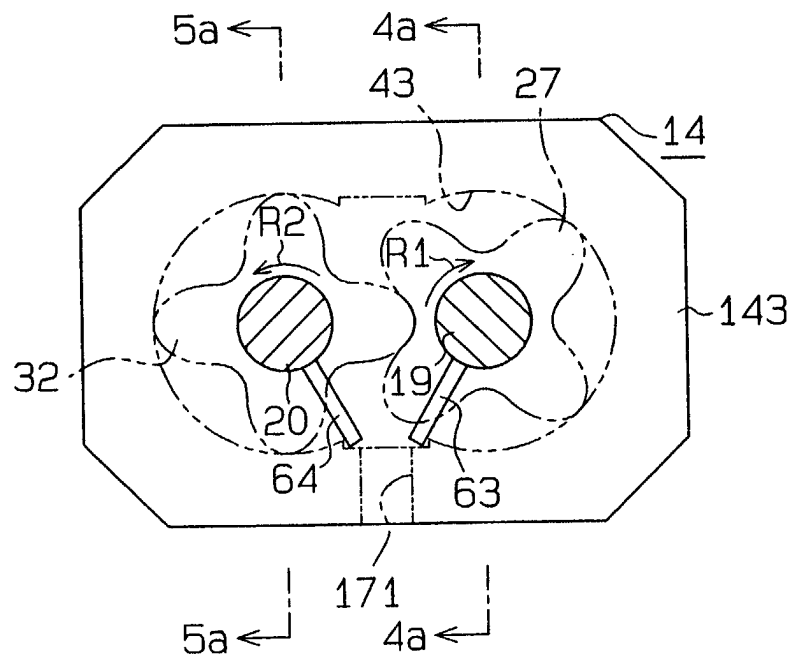


Fig. 4(b)

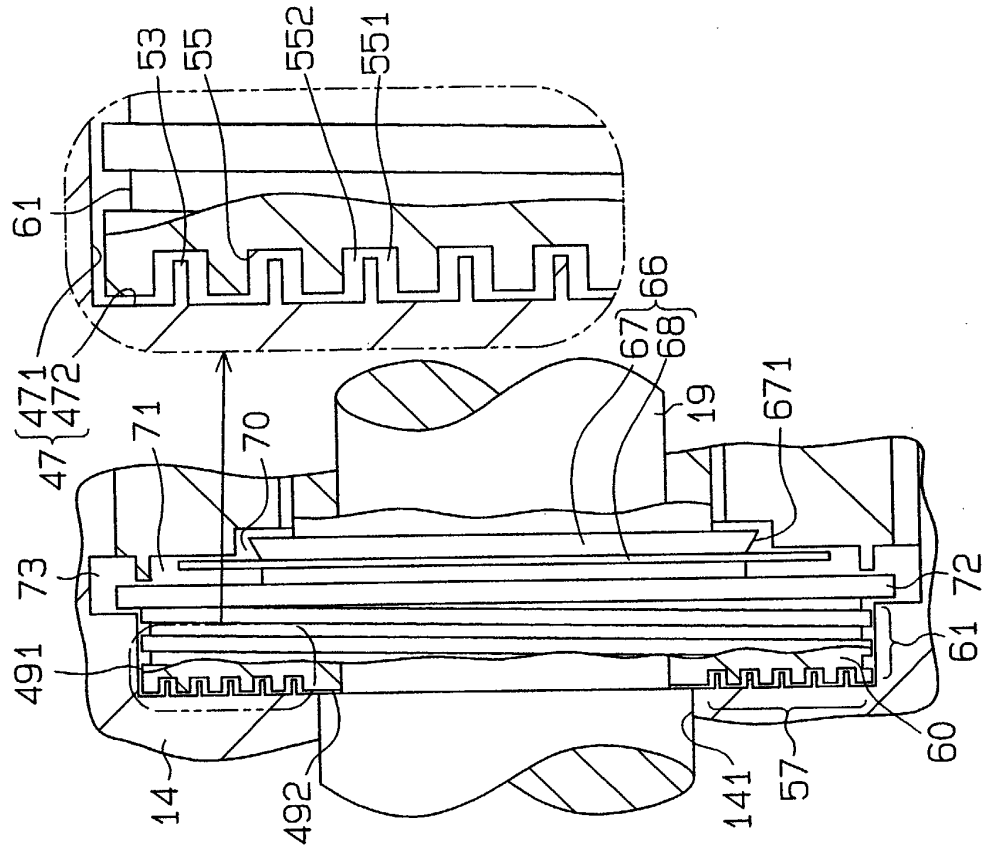


Fig. 4(a)

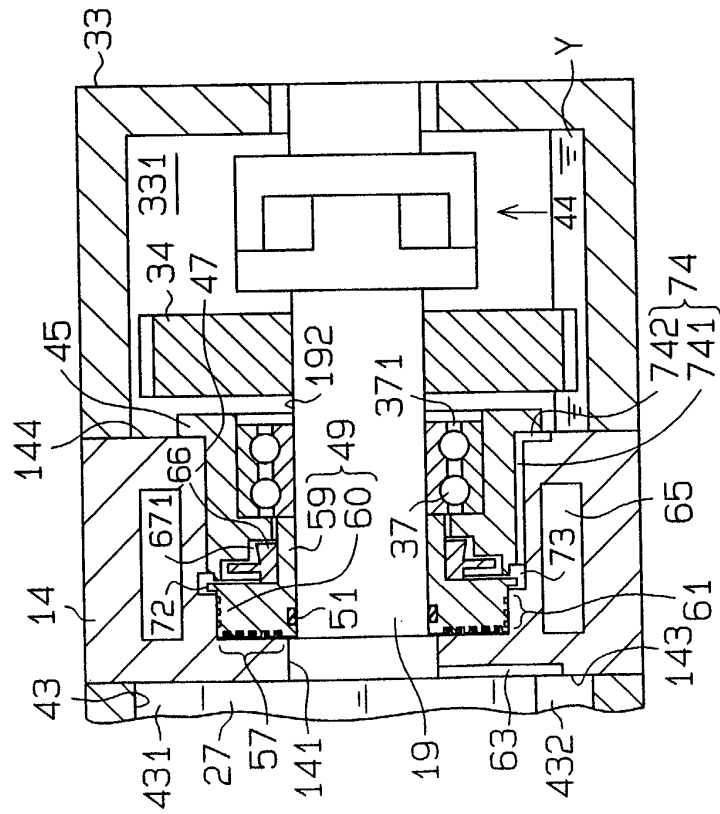


Fig. 5(a)

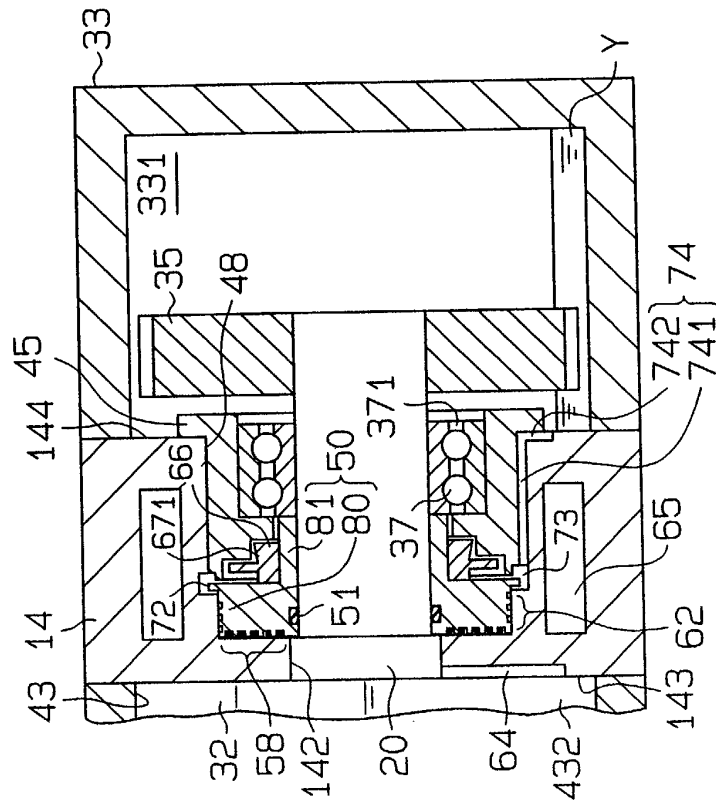


Fig. 5(b)

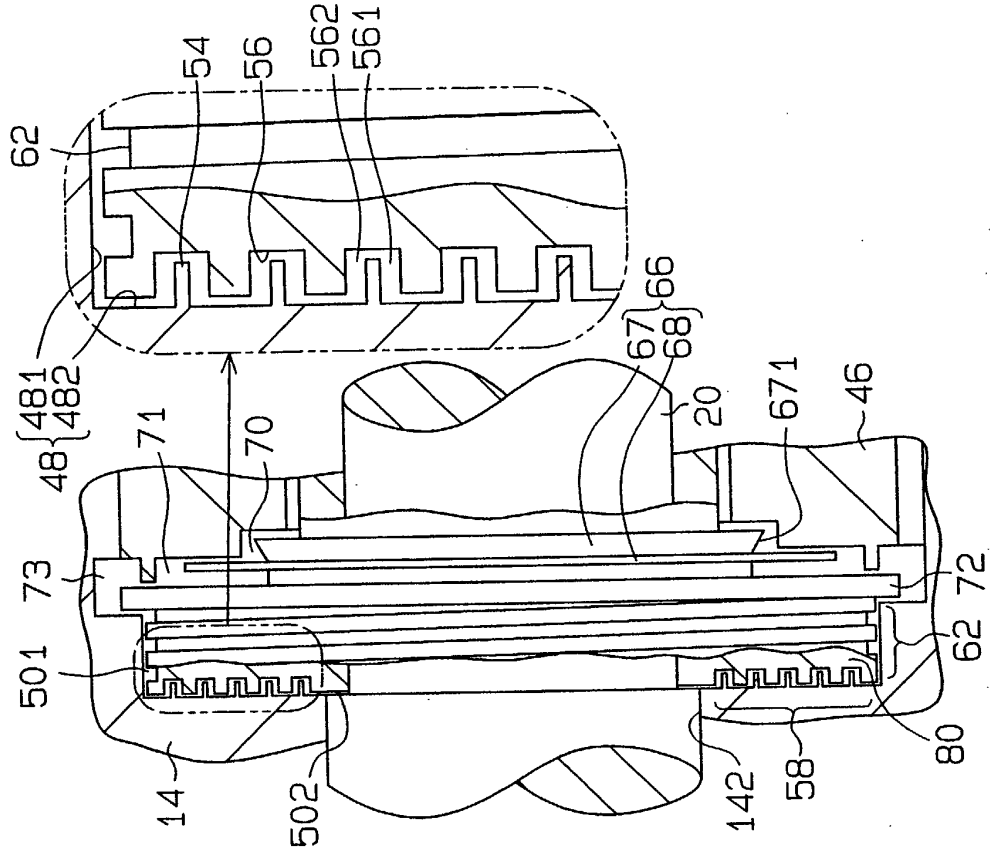


Fig. 6(a)

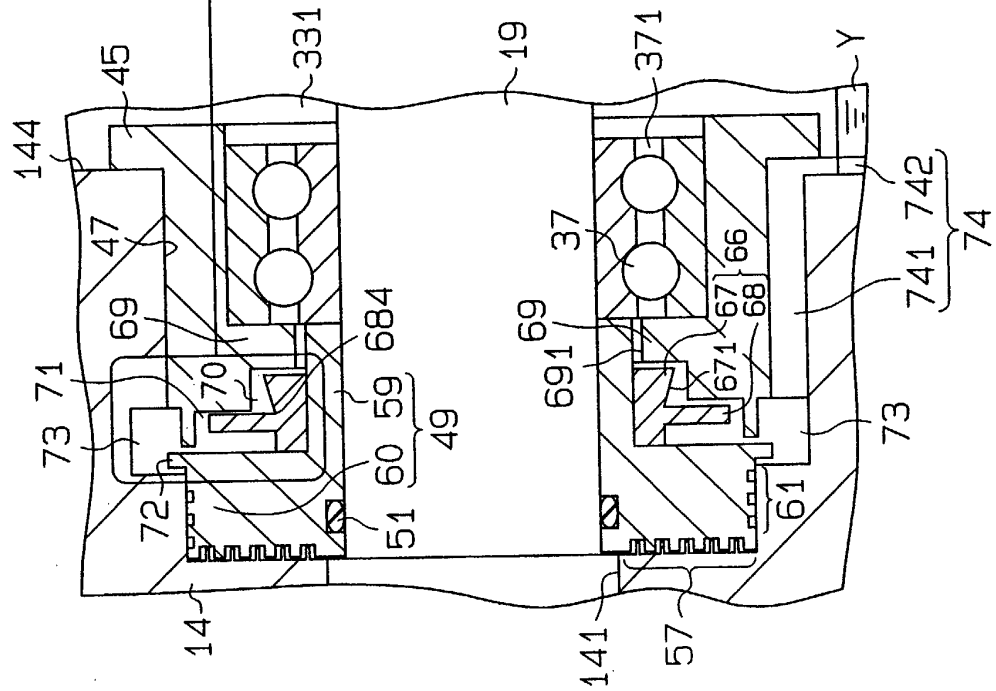


Fig. 6(b)

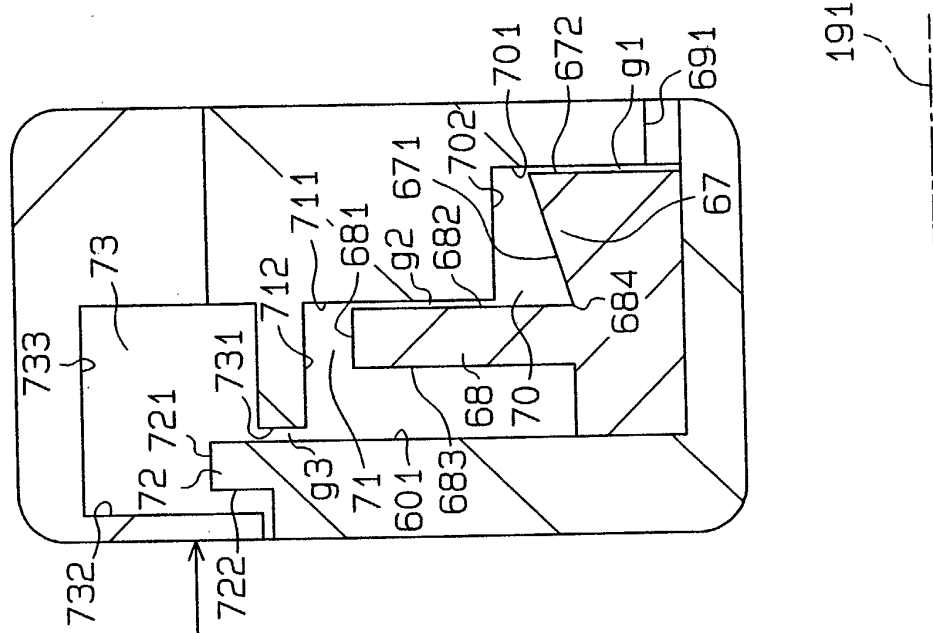


Fig. 7

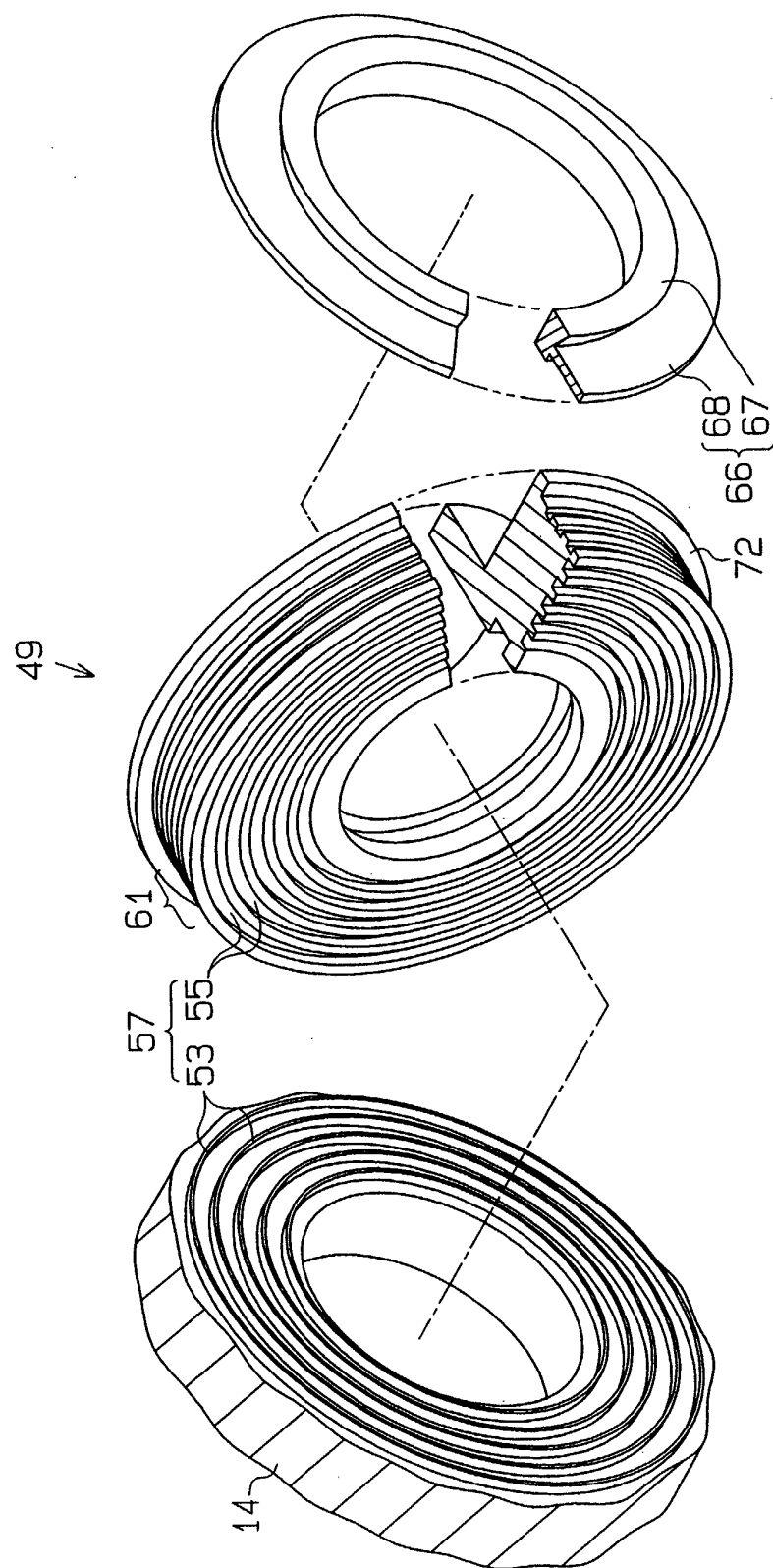


Fig. 8

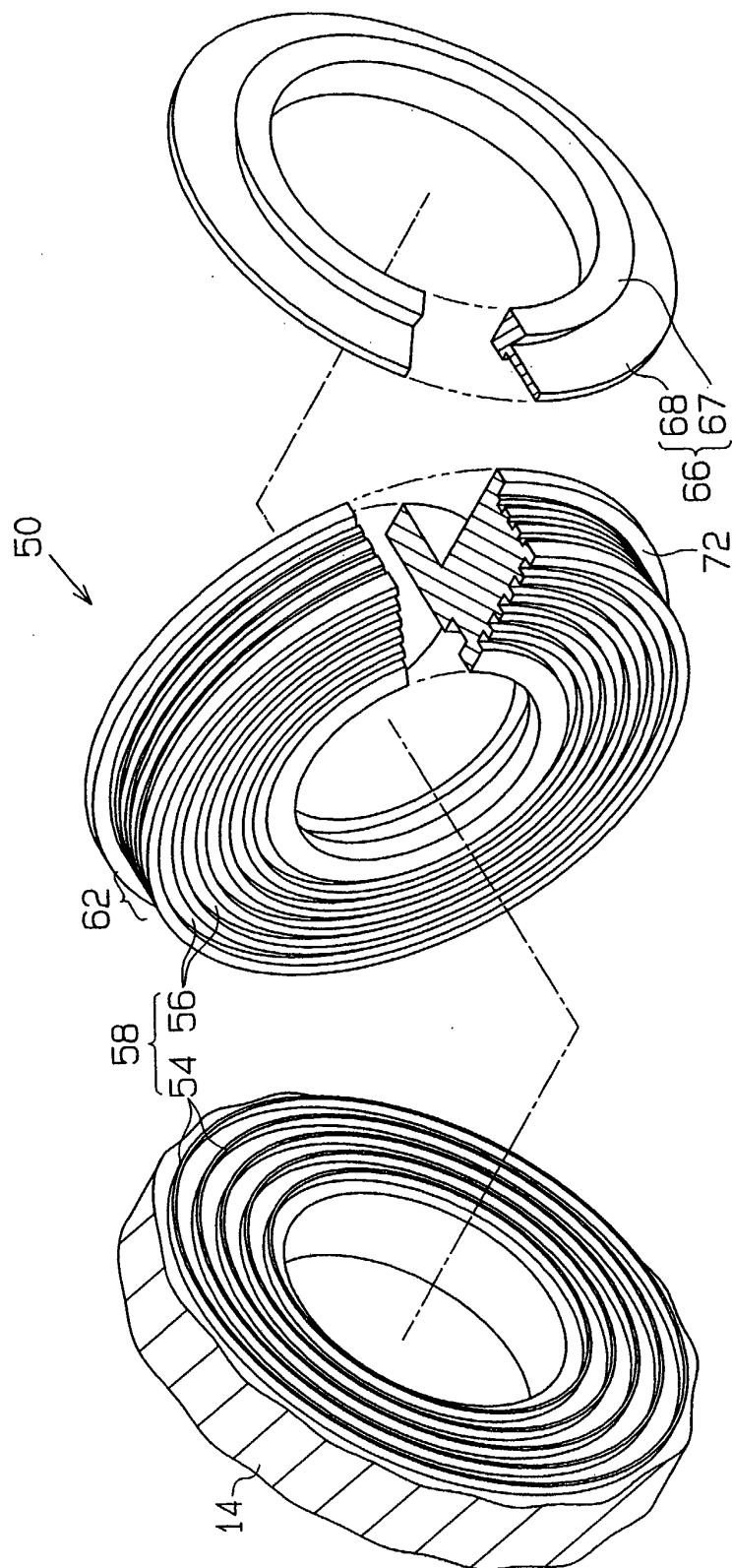


Fig. 9

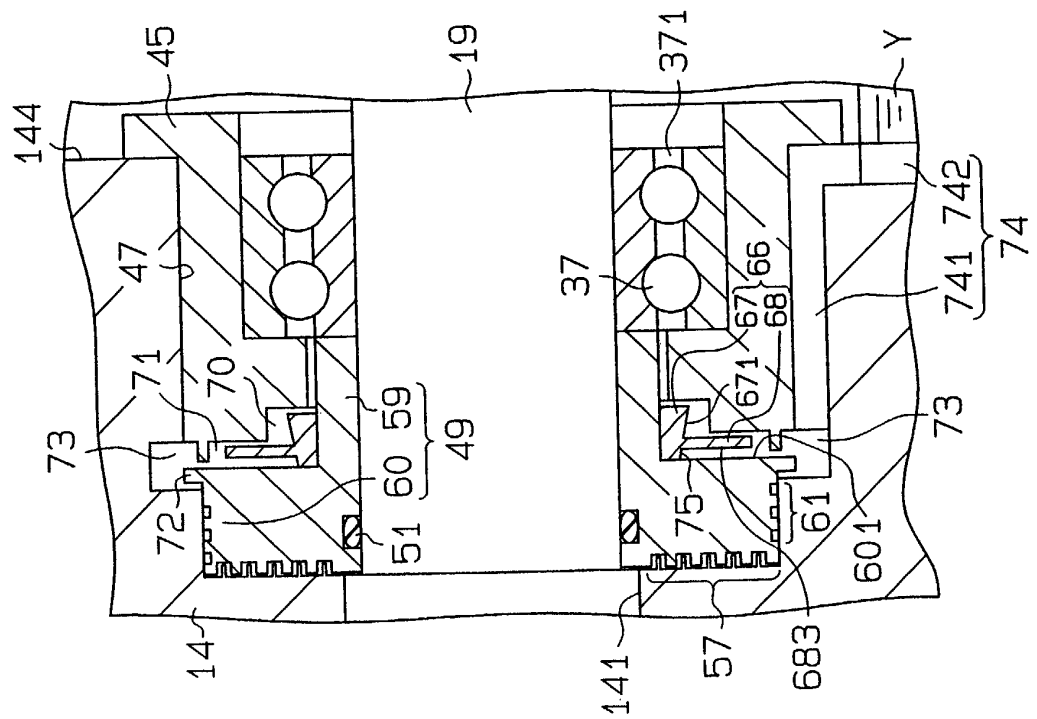


Fig. 10

